1997-10-23

Power Available vs Power Required, the saga continues.....

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http://hdl.handle.net/10945/35030

Power Available vs Power Required,

the saga continues....

by Major David P. Lobik

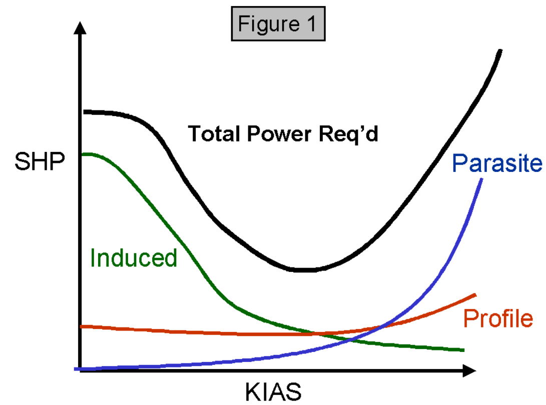
The mishap investigation report read: "The helicopter was operating near max gross weight and drooped turns (main rotor revolutions per minute) at the bottom of the approach to the unfamiliar mountainous landing zone (LZ). On takeoff, the pilots realized too late that the power required to depart the LZ was more than normally available at sea level. The aircraft impacted the terrain." Sound familiar? All Navy/Marine helicopter communities have learned this lesson the hard way and though the relationship between power available and power required is recognized, it's often misunderstood.

Several Navy/Marine helicopter mishaps have occurred over the recent and not so recent past that would have been prevented with a solid understanding of the power relationship and exercising a little risk management. We in the helicopter flying business receive excellent instruction in the training command on the subject, however, knowledge and skill are both perishable and it has been proven that even the most experienced aviators suffer from a lack of understanding. Let's revisit this issue by taking a look at what comprises the power required and power available charts and of course, the main factors that affect both: gross weight and density altitude (DA).

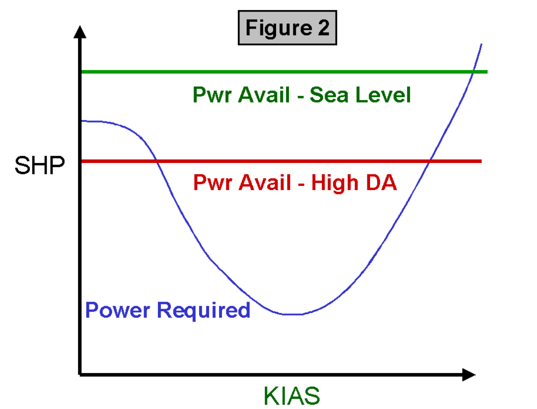
All helicopters with either a single main rotor or a tandem rotor configuration display a similar power required curve. This power required curve is made up of three power requirements - induced, profile and parasite, each demonstrating a dominance in a particular airspeed range. First, let's discuss the induced power requirement. Induced power is what people are referring to when they say helicopters "beat the air into submission." Newton's 2nd law concerning action-reaction applies in this regime where we must force air down to keep the aircraft aloft. In fact, approximately 70 - 80 % of the power required in a hover is induced power and is directly proportional to weight and DA; therefore, as aircraft gross weight or DA increases, so does the induced power required.

Secondly, we have the profile power requirement to overcome all form drag and skin friction that occurs with a rotor blade at a local zero lift condition; in other words, it's the drag of the blade at flat pitch. Look at it as the resistance that results when moving an object through the air that is producing lift such as rotor blades and vertical or horizontal stabilizers. It is proportional to forward flight speed (squared) and blade pitch, yet inversely proportional to DA.

Thirdly, parasite power is the power required to overcome the "barn door" effect. Those objects exposed to the relative wind that do not generate lift decrease our performance as airspeed increases. In a nutshell, it takes more power to move a non-aerodynamically shaped object through the air than one that is designed as a lift-generating surface. Speaking of moving barn doors through the air, designers of helicopters will work feverishly to reduce the nose-down attitude of the aircraft in high speed flight with the hopes of minimizing the area exposed to the air thus resulting in less resistance. This type of power required can be significant, especially at the upper end of our airspeed range due to its proportionality to flight speed (cubed). For example: in addition to the fuselage, the sponsons, external fuel tanks, missile launchers, and all contribute to providing unwanted resistance against the wind. Air has a difficult time negotiating sharp turns as it passes around components on our aircraft. To decrease the parasite drag doesn't necessarily mean to make it smaller, but rather, to aerodynamically shape it to move the air around the object with the least amount of turbulence. It's not by luck that external fuel tanks are not shaped like bricks!



The curves shown in Figure 1 represent the contribution of each type of power to the power required charts that we find in the back of most helicopter NATOPS manuals. These charts are normally represented as a family of curves corresponding to various aircraft gross weights, temperatures and pressure altitudes or DA and are also based on level, unaccelerated flight. From the Figure, it becomes apparent that induced power dominates the power required in the low airspeed regime to include the hover and decreases as the airflow through the rotor system increases providing for better rotor performance. Now, as the helicopter progresses through translational lift, airspeed increases and profile power kicks in. Again, the lifting surfaces such as the rotor blades fight the resistance as they slice through the air resulting in this increased power demand. As we continue to pull collective and approach cruise speeds, the parasite power requirement takes off! As seen in Figure 1, the power required to move a helicopter to velocity-not-to-exceed airspeed (V_{NE}) is quite significant and usually greater than hover power, but not always. This discussion on the power requirement curves will now help us analyze helicopter performance in the worst of fly conditions such as the high, hot and heavy environment.



But first, let's take a look at power available. Unlike jet engines on fixed wing aircraft, helicopter turbo-shaft engines do not show an appreciable increase in power available as a result of the inlet pressure rise associated with ram air. Therefore, helicopters demonstrate roughly the same power available in a hover as they do at V_{NE} airspeed. This is all well and good, but what happens with changes in DA and gross weight? All jet engines need to balance a proper fuel-to-air ratio to ensure maximum efficiency at all torque settings. If the air gets thinner as it will with an increase in DA, then the fuel introduced by our fuel management systems becomes less thus limiting the power available. Why? Because jet engines operate most efficiently when the fuel-to-air ratio is held constant for combustion. Therefore at high altitudes and temperatures, most engines can not provide all the horsepower the transmission can handle which means the power available line in Figure 2 will shift downward. This is occurring at the same time that the rotor system is requiring more air to produce lift; the result is a higher collective setting thus, more power required.

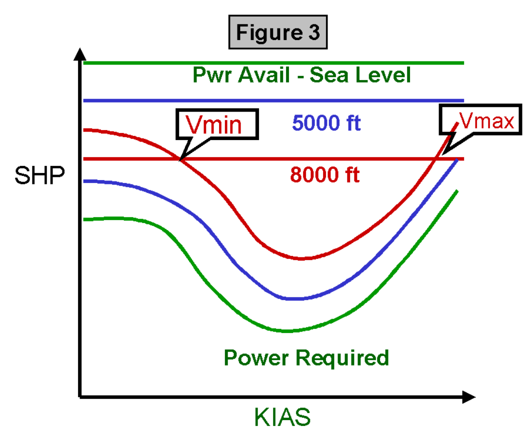


Figure 3 shows a representation of the power required curve merging with the power available, again, perhaps a high, hot and heavy situation (notice the region of deficit excess power). If the aircraft is flown at an airspeed below the left intersection (Vmin) or above the right intersection (Vmax) of the power required and power available curves, then the aircraft experiences a decrease in RPM and a descent follows--a typical result when power required exceeds power available.

An extreme example of a high DA and gross weight situation is the Mount Everest rescue of 1996 where a Nepalese helicopter pilot volunteered to rescue climbers after the area contract pilots refused to accept the mission due to the altitude and poor weather conditions. LtCol Maden K. C. of the Royal Nepalese Army understood very well the power requirements of his single engine AS 350. He was the officer that on May 13, 1996, rescued an American and a Taiwanese at an elevation of 20,000 ft. on the slopes of the highest peak in the world. He flew 2500 ft. above the helicopter's 20,000 ft. service ceiling to get over a ridgeline where he was successful in locating the climbers. After several landing attempts that resulted in a decrease in RPM and loss of altitude, he realized the need to shed some weight so he continued down the mountain to a lower elevation to drop off his copilot. As the afternoon sun began setting, he still knew the helicopter would have a difficult time hovering *in-ground-effect* so a no-hover landing was attempted. Concerned with the firmness of the snow, he hoped for hardpack and got it. He stayed light of the skids and took one climber at a time, staying in- ground-effect until he could push the nose of the helicopter over to pick up airspeed while following the down-sloping terrain. He successfully picked up the second climber in the early evening and is credited with performing the highest helicopter rescue in the world. Only through his familiarity with the austere flying environment and precise understanding of power available verses power required was the LtCol able to successfully achieve such a mission!

In conclusion, a change in aircraft configuration, gross weight and environment should activate a switch inside our helmet telling us to closely review the power computation sheet and understand what these changes do to helicopter performance and above all, fly the charts!

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Updated: ***23 Oct 97.***